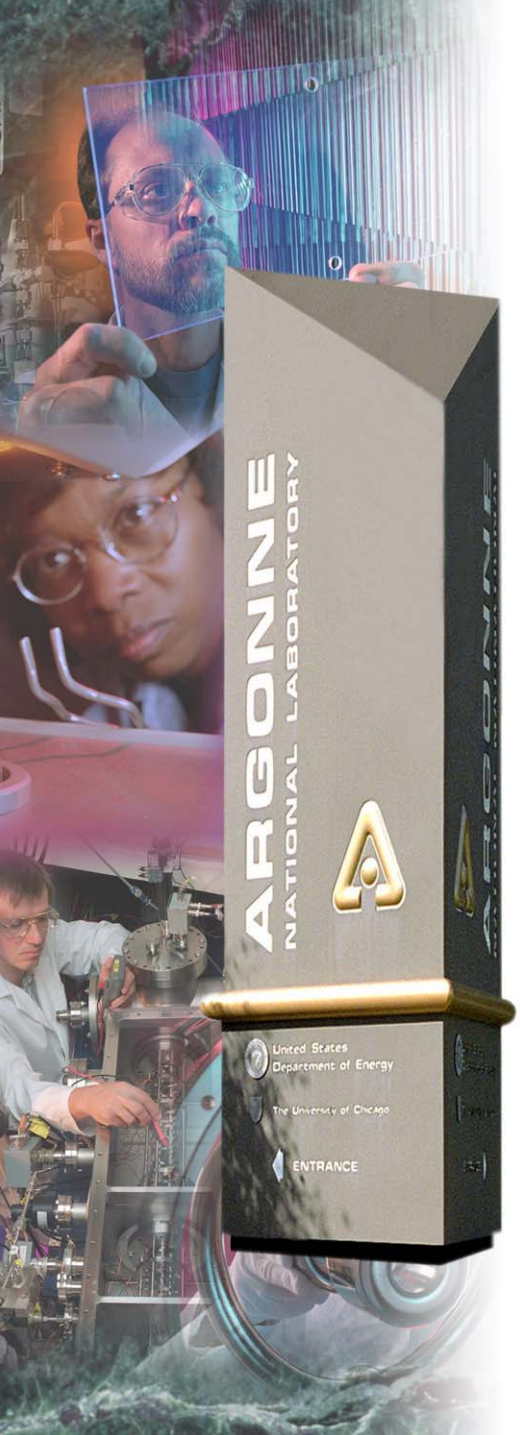

The Development of Complex Adaptive Systems Based Decision Support Systems

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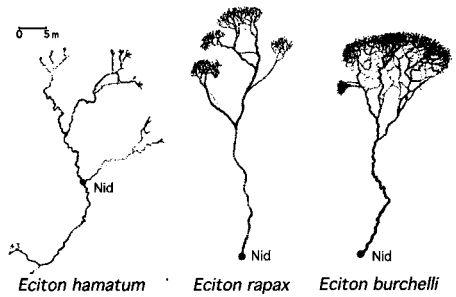
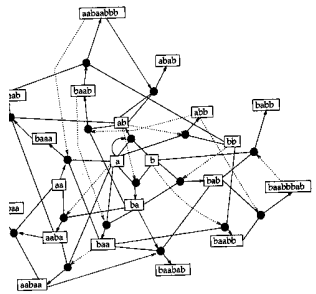
Briefing Outline

- High Level Overview of Complex Adaptive Systems
- Examples of Argonne CAS Decision Support Systems
- Summary

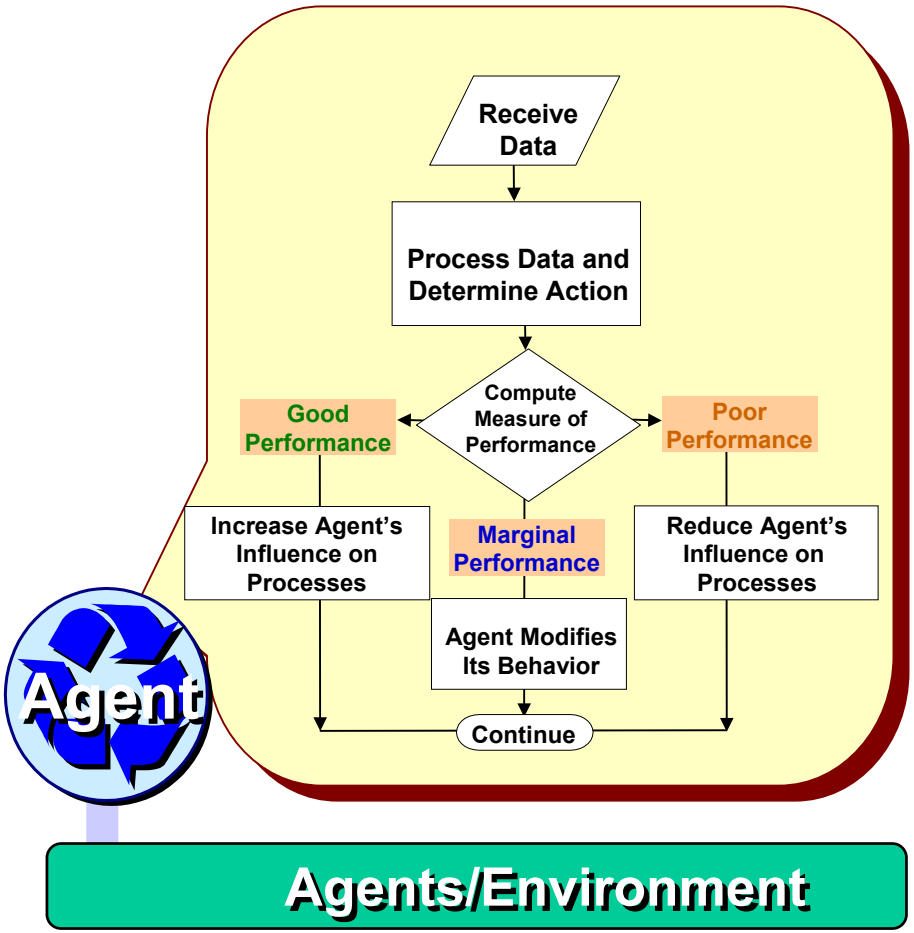
A Complex Adaptive System Consists of Agents That Interact While Adapting to their Environment

- Human immune system
  - Agents: antibodies
- Ecosystems
  - Agents: species, individuals, hives, flocks
- Economic markets
  - Agents: producers, distributors, consumers
- Electric utility markets
  - Agents: generators, transmission companies, brokers, consumers





An Agent is a Software Representation of a "Decision-making" Unit



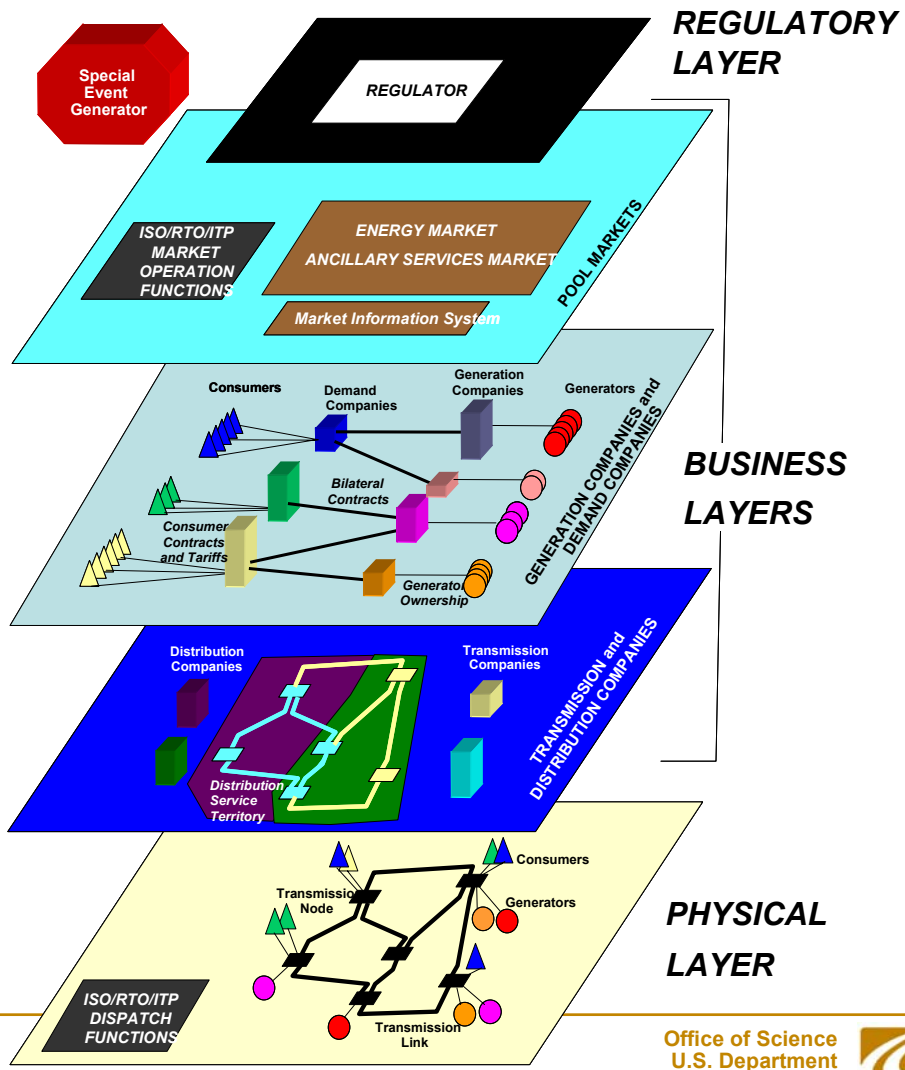
- An Agent has:
  - Set of decision rules
  - Ability to change or *adapt* decision rules over time
  - Measures of performance applied to its decisions – by itself and by the environment
  - Internal models of the environment and of other agents' decision processes
- Agent Interactions can lead to Self-organization and Emergent Structure

Argonne Is Applying Complex Adaptive Systems (CAS) Simulation in Several Applications

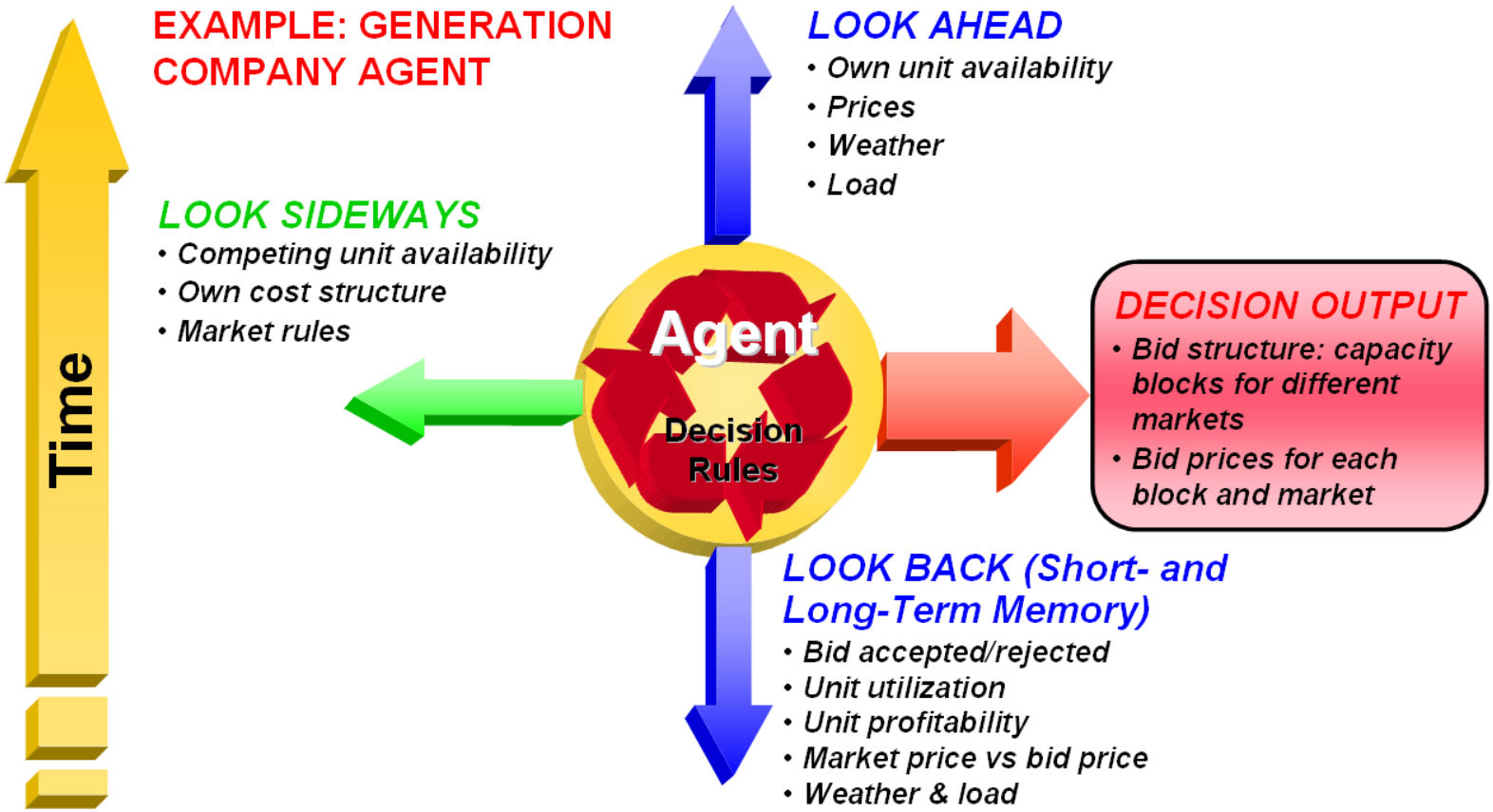
- **Electricity Markets***:* EMCAS is a Repast model that simulates complex, realistic energy markets
- **Infrastructure Interdependencies***:* Interdependencies among natural gas, electric power, telecommunications, and petroleum networks
- **Counter-drug Interdiction:** Develop and analyze blue and red counter-drug strategies for countering drug trafficking
- **Adaptive Communication Networks:** Tactical Sensor and Ubiquitous Network Agent-Modeling Initiative (TSUNAMI), addresses the Navy's shift from platform-centric to network-centric warfare
- **Terrorism***:* NetBreaker for identification of hidden networks based on partial information

EMCAS is a Model of Decentralized Electricity Markets

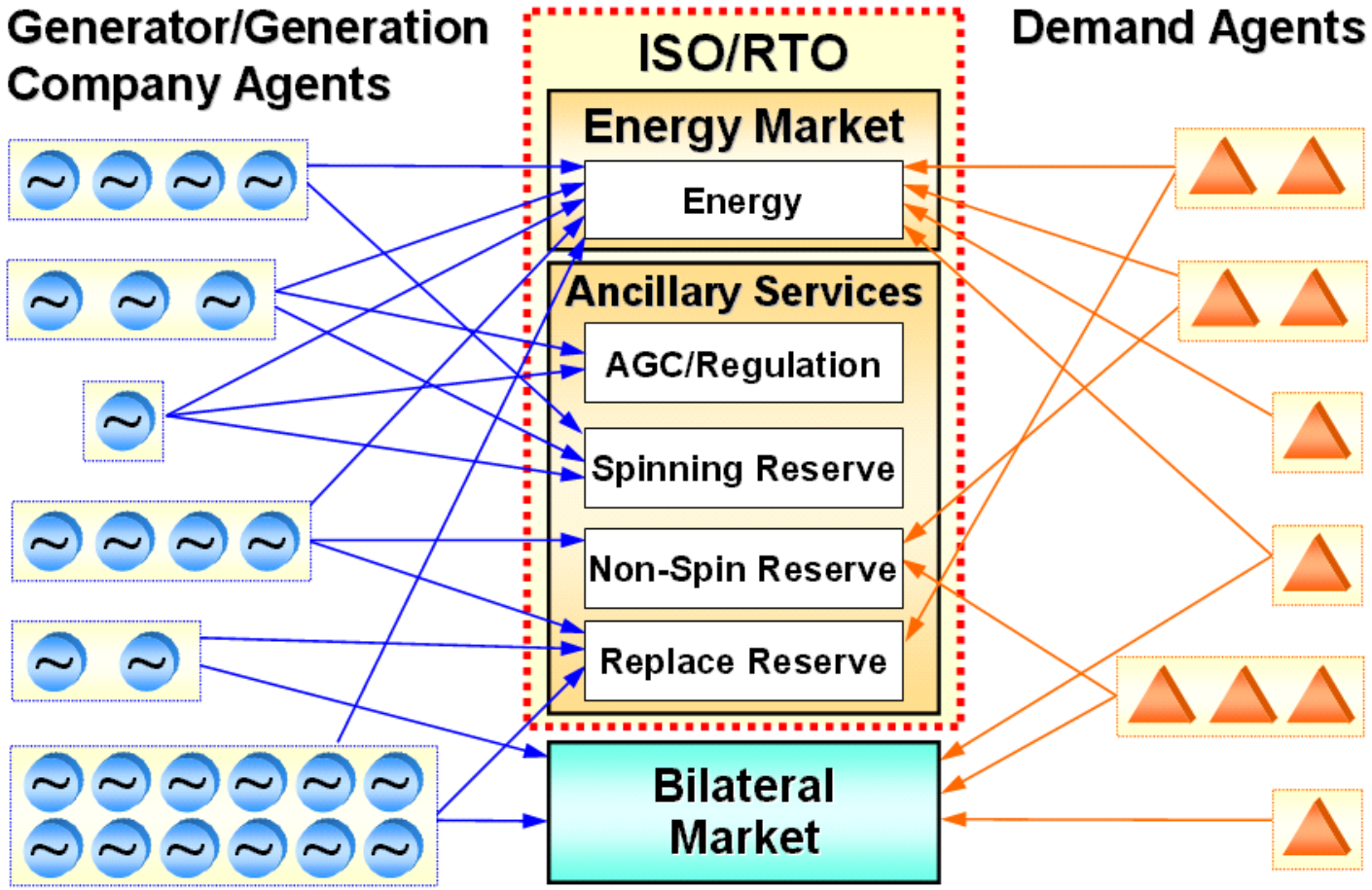
- The Electricity Market Complex Adaptive Systems (EMCAS) model is an agent-based electricity market model written using Repast
- EMCAS agents take on the roles of individual market participants



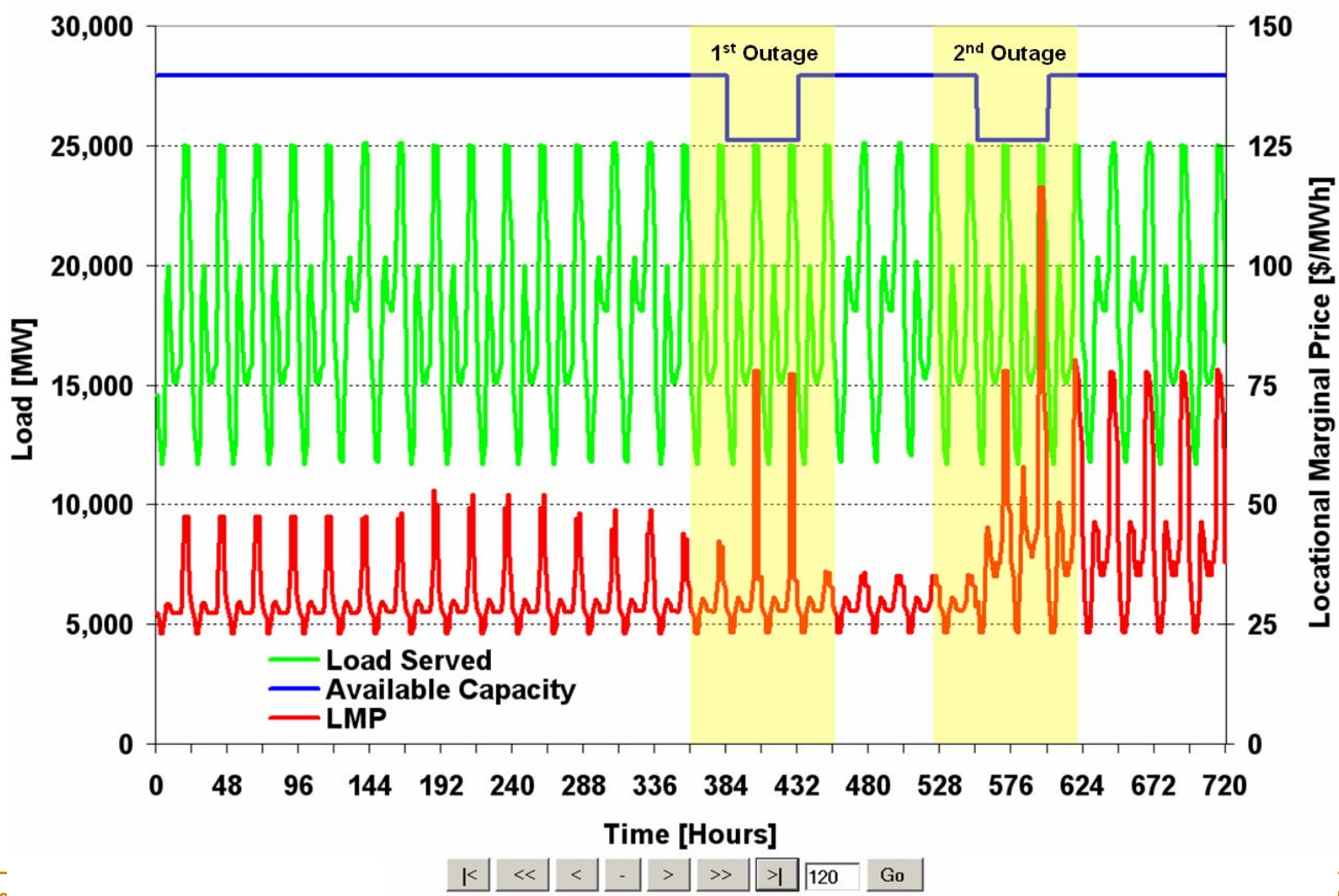
EMCAS Generation Company Agent Decisions are Based On Several Factors



EMCAS ISO/RTO Agents Match Independent, Decentralized Buyers and Sellers



EMCAS Agents Learn About Their Market



EMCAS is Currently Being Used for the Illinois Commerce Commission

- EMCAS is being used to Investigate the Dangers Posed by Possible Transmission Constraints in Illinois in 2007 and beyond
- EMCAS Agents are being used to Simulate Specific Market Participants
- EMCAS is being used to Determine the Kinds and Magnitudes of Threats Presented by Possible Transmission Constraints

CASCADE-CD: Complex Adaptive System Countermeasures Analysis Dynamic Environment

- CASCADE-CD is the Complex Adaptive System Countermeasures Analysis Dynamic Environment for Counter-Drug Applications
- Program Sponsor: The Joint Staff/J-8
- Intended Roles:
  - Aid drug analysts in deriving and justifying force structures and operational planning recommendations
  - Serve as a “test bed” for the use of Complex Adaptive Systems techniques in “industrial strength” DoD applications, such as developing new force structures

Scope of the CASCADE-CD Development Effort

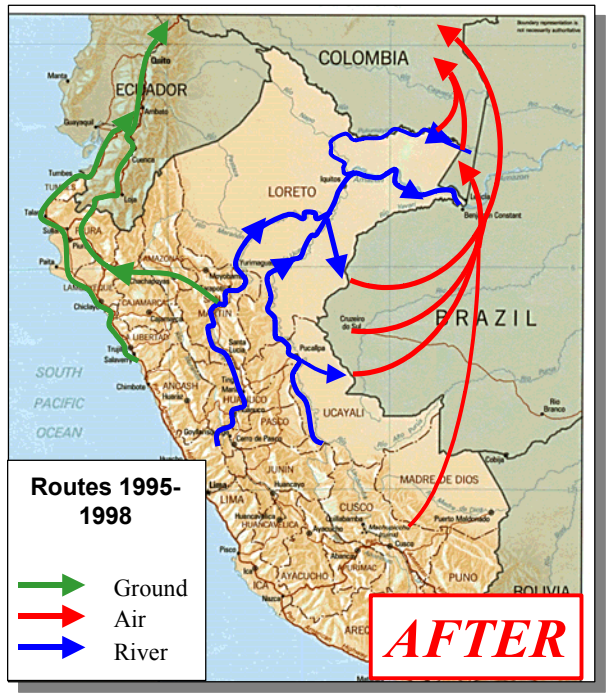
FOCUS IS ON:

- *"Transit Zone" (Eastern Pacific, Caribbean, Central America), with limited representation of the "Source Zone" (e.g., Peru, Colombia, Ecuador).*
- *Cocaine trafficking (not other illicit drugs).*
- *"Primary movement" - the phase of a cocaine smuggling attempt in which cocaine first leaves the Source Zone.*

EXPLICITLY MODELED:

- *The entire interdiction chain: intelligence cueing, detection, sorting, monitoring, interception, visual ID, tracking, and law enforcement "endgame."*
- *Actual geography and attendant geographic and geopolitical constraints. Drug trafficker "enterprise" activities embedded in South American socioeconomic matrix*
- *ADAPTIVE behaviors of both interdictor and drug trafficker agents manifested at several scales and granularities*

Scope of the CASCADE-CD Development Effort: Basic Problem Space



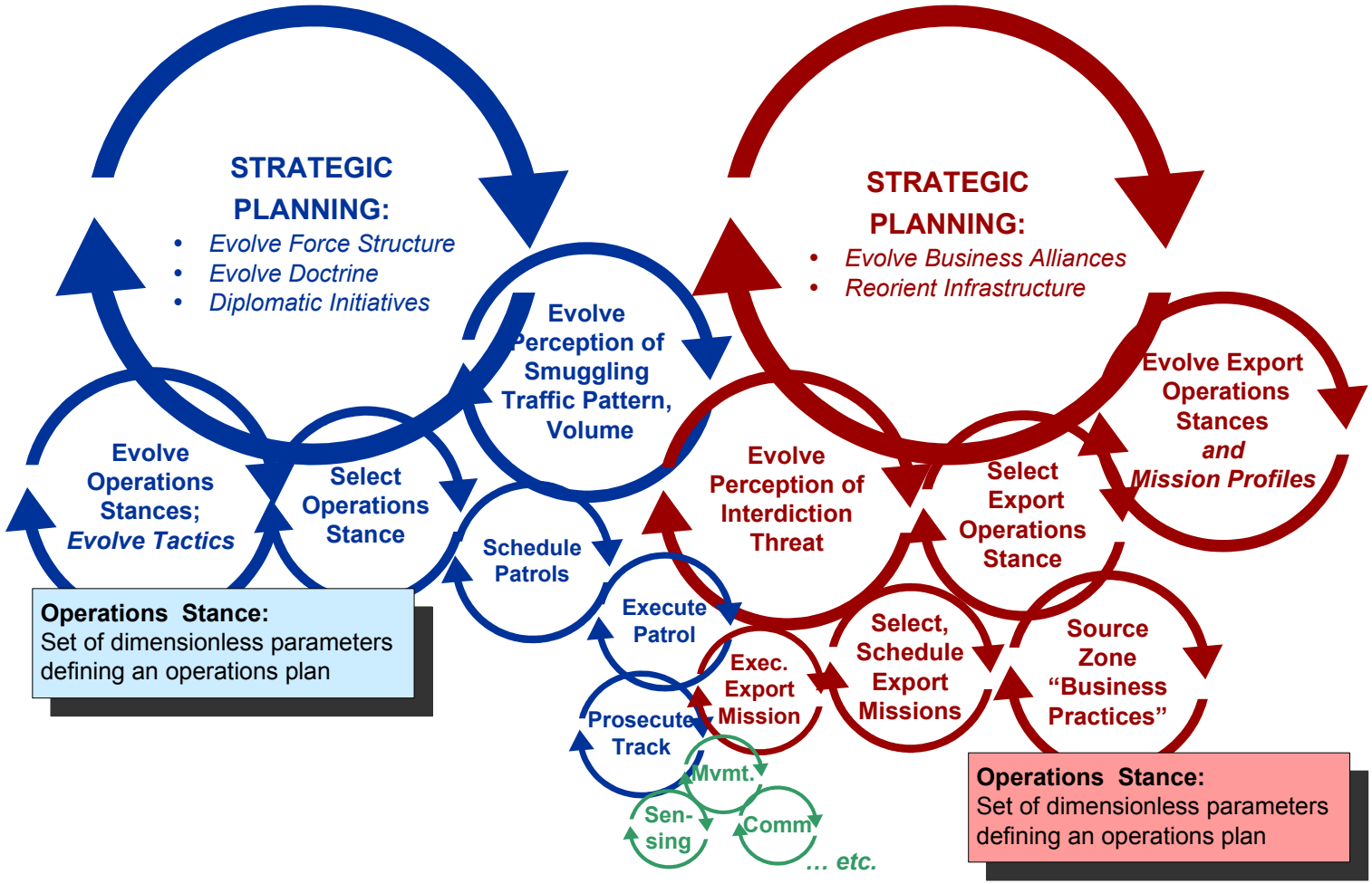
Blue builds Force Structure based on "local" success

- Assumes static red
- Optimizes for Air

"Frustrated" Red Adapts its Air, Ground, &/or River Movement

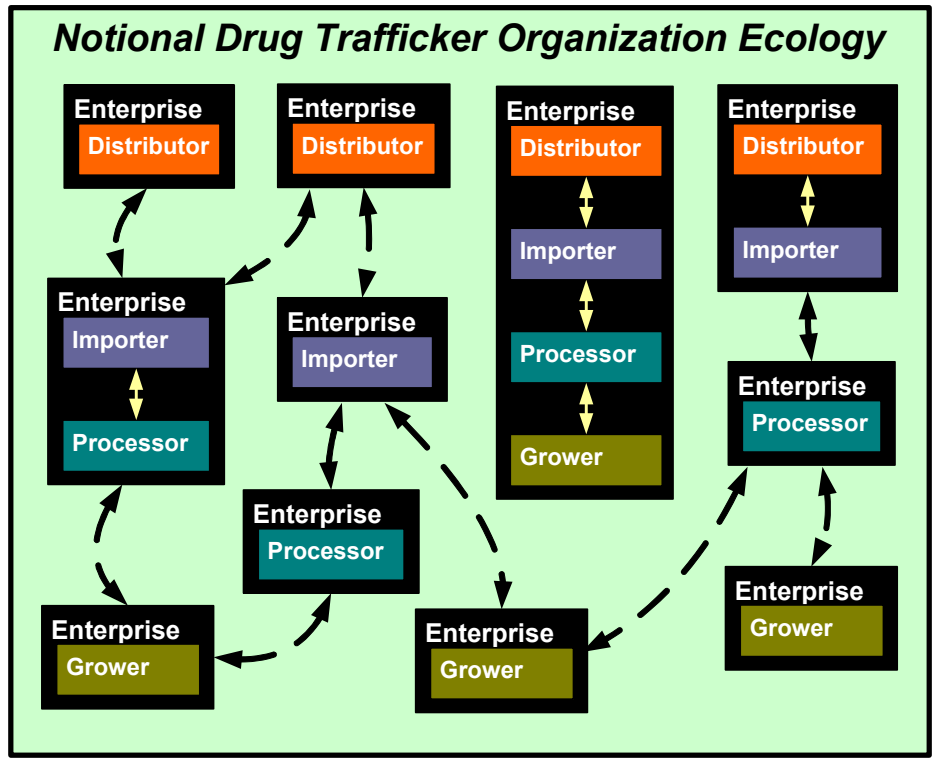
- Low cost to make change
- Renders blue force structure less effective

CASCADE-CD: Scale and Scope of the Dynamic Processes that are Modeled



CASCADE-CD: Counter Drug Idiosyncrasies

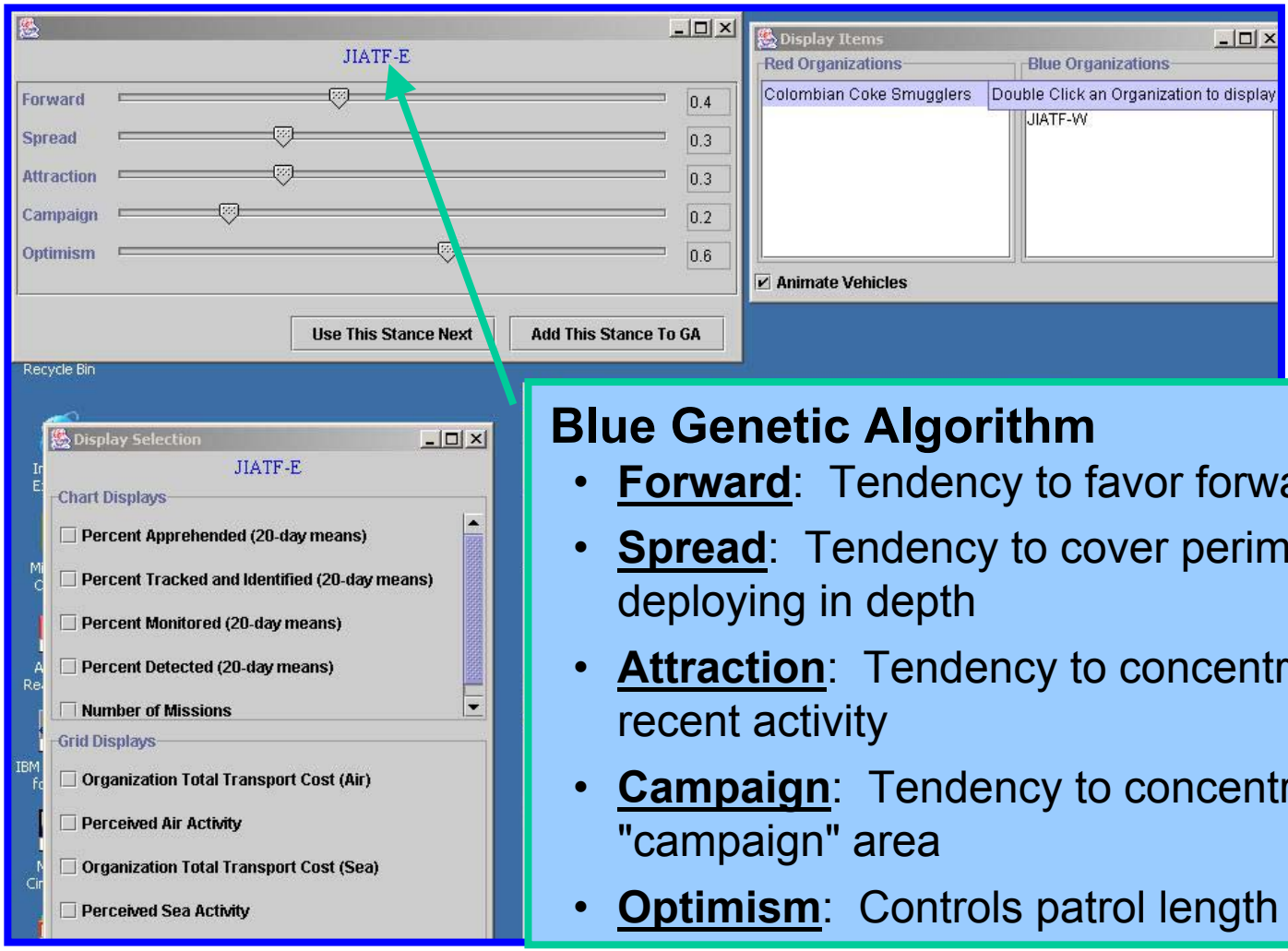
- The CD Opponent is not Monolithic: It is an "Ecology" of Diverse Organizations
- The "Cocaine Trade" Represented is the Emergent Behavior of the Ensemble of "Agents" working their own Agendas.
- CD is Strongly Asymmetric with Respect to C3:
  - Blue tends to conduct theater CD operations under centralized control
  - Red is communications averse



An unusually high degree of coordination across diverse organizational boundaries (US military, PNs, LEAs) is required for success.

Especially true in dealing with air tracks, where timing is everything.

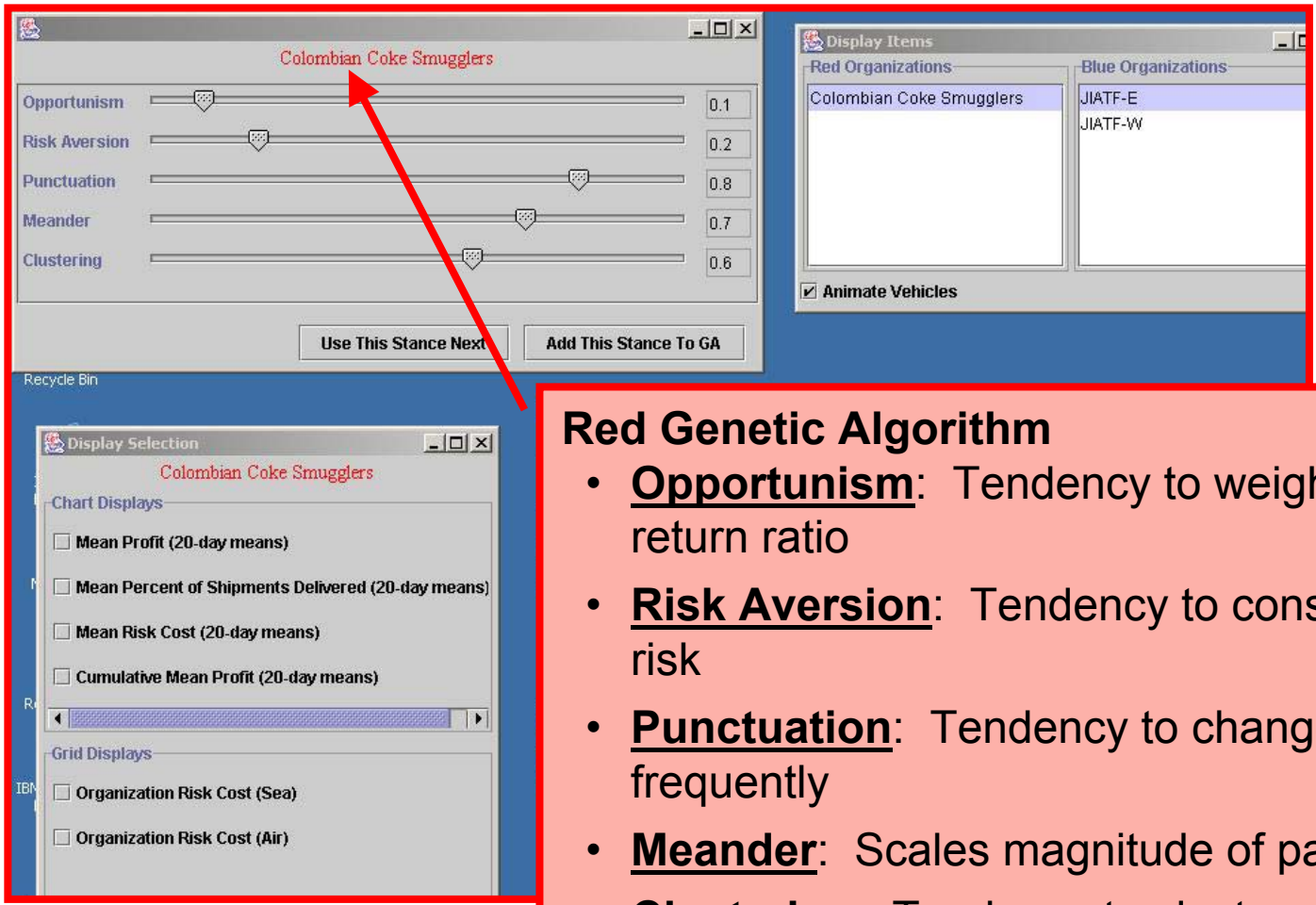
CASCADE-CD: Interdictor and Drug Agent Representation – Blue



Blue Genetic Algorithm

- **Forward**: Tendency to favor forward patrol areas
- **Spread**: Tendency to cover perimeter vice deploying in depth
- **Attraction**: Tendency to concentrate to cover most recent activity
- **Campaign**: Tendency to concentrate in single "campaign" area
- **Optimism**: Controls patrol length for coverage

CASCADE-CD: Interdictor and Drug Agent Representation - Red

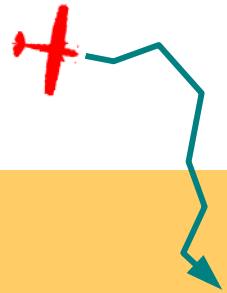


Red Genetic Algorithm

- **Opportunism**: Tendency to weight projected return ratio
- **Risk Aversion**: Tendency to consider perceived risk
- **Punctuation**: Tendency to change vectors frequently
- **Meander**: Scales magnitude of path deviations
- **Clustering**: Tendency to cluster missions

CASCADE-CD: Agents can Dynamically Change in Response to their Environment

- In CASCADE-CD, Drug Trafficker's may Adaptively Vary their Route



Smuggler's view of Pros and Cons of highly elaborated routes:

CON:

My route is now longer, so:

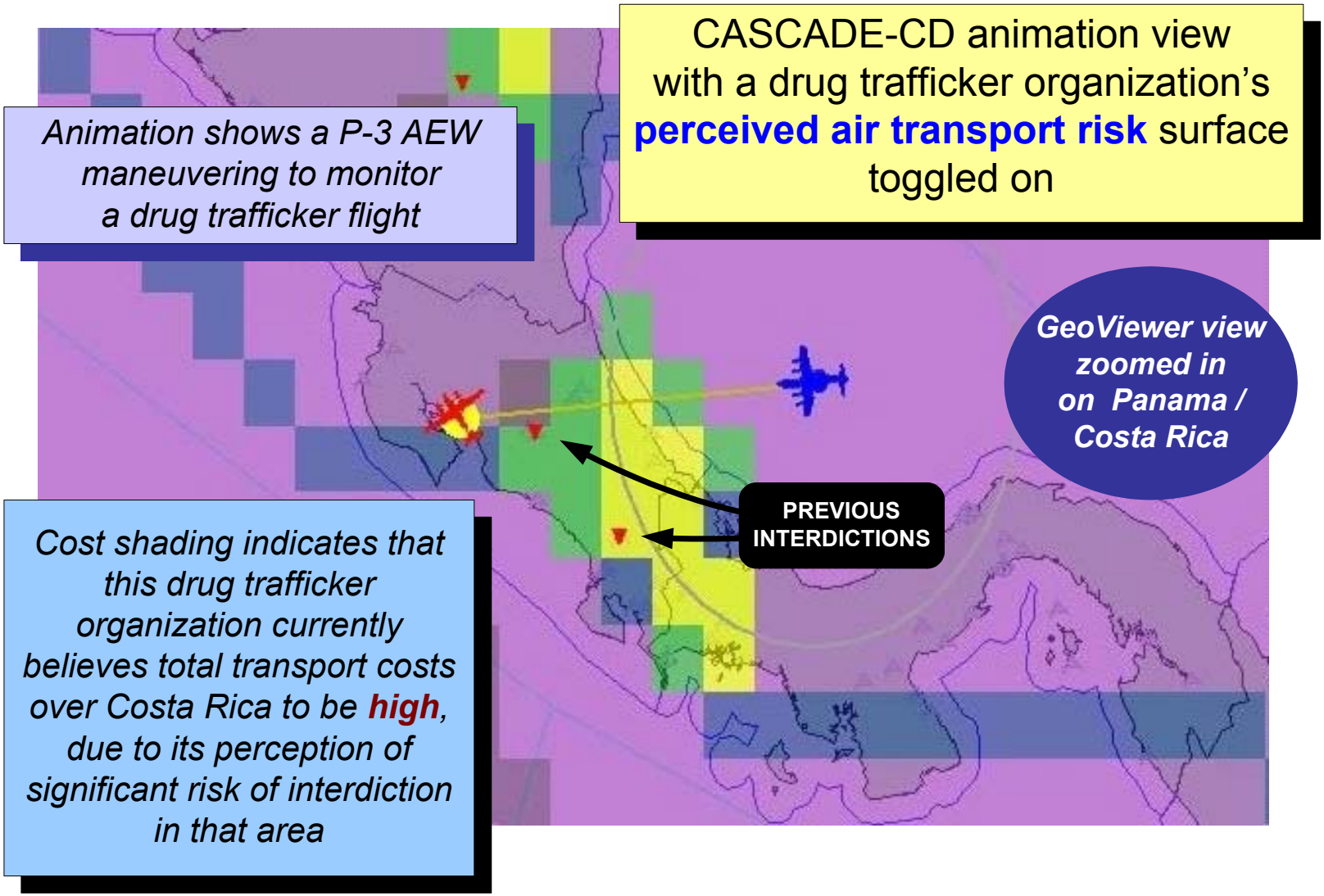
- *I'm exposed to interdiction longer;*
- *Some attractive destinations are now out of my range.*

PRO:

Since I'm changing vector so often, interdictors may have more trouble detecting / sorting / monitoring me, so I ought to be safer.

- CASCADE-CD also Explicitly Models the Sensitivity of Sensor Performance to Target Aspect / Radial Velocity and Time Since a Target's Last Vector, so these Dynamics can also be Captured

Example of CASCADE-CD Results



Summary

- Agent Technology Provides a Mechanism to Capture how Entities can Dynamically Respond to their Environments
- *Complex* Adaptive Agent System Applications are Being Used to Dynamically Model Environments in which the Driving Forces can be Physics or Socially Driven
- Argonne is Developing and Implementing Complex Adaptive Agent System Simulations to Address a Variety of Problems of National Importance

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